

# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

### Radar System

5 We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63, Aldwych, London, W.C.2, England, do hereby declare the invention, (A communication from Nippon Electric Company Limited, a Japanese Company, of 2, Siba Mita Shikoku-machi, Minato-ku, Tokyo, Japan), for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 This invention relates to a radar system in which the transmitted wave is in the form of pulses.

15 The invention will be understood by reference to the following description of an embodiment thereof taken in conjunction with the accompanying drawings in which:—

20 Fig. 1 shows an example of waveform of the transmitting wave used in a radar system of this invention. Fig. 2 is a block diagram of the radar system. Fig. 3 shows an example of the construction of a decoding circuit used in the receiver section of the radar system. 25 Fig. 4 is a time sequence diagram of pulses at outputs of the decoding circuit.

30 It is a well known fact that the conventional pulse radar is comparatively easily interfered with by another electric wave of the same frequency or in particular by another electric wave intended for interference, the function being seriously impaired. Although a method of altering the frequency of the transmitted signal as a means for avoiding the interference is easily conceivable, in the case of intentional interference the altered frequency can be measured and the interference renewed at that frequency. This, therefore, provides no radical solution. As another method, a method of pulse code used for conventional electric wave equipment such as friend or foe identification equipment is conceivable. This method, however, depends on the amplitude of the transmitted radar signal with the result that a

45 method of performing effective interference can be discovered by simple measurement of amplitude waveform.

The present invention aims to provide an anti-jamming radar system which is incapable of being easily interfered by simple measurement.

50 The present invention will now be described referring to the accompanying drawings, wherein Fig. 1 shows an example of the transmitting wave with time T and amplitude A taken as the abscissa and the ordinate respectively. As is evident, the transmitting wave forms a pulse series composed of a plurality of elementary pulses 1, 2, and 3 with amplitude  $a$ . Let the pulse intervals between pulse 1 and 2, 2 and 3 be  $\tau_1$  and  $\tau_2$ , respectively. Although the relationship between  $\tau_1$  and  $\tau_2$  may be arbitrary, an explanation will be given below for a case wherein  $\tau_1$  is greater than  $\tau_2$ . Let it be assumed that particular coding be performed at the carrier phase and the phase of 1 differs from the phase of 2 and 3 by  $180^\circ$ . This is the reason why oblique lines are provided in pulse 1.

70 It is also assumed that the well-known superheterodyne system is used for the receiver. Fig. 2 illustrates one example of the radar system in a block form. In this figure, a decoding circuit is at the intermediate frequency stage. Although, in the principle it may be placed at the radio frequency stage, the case of an intermediate frequency decoding circuit only will be mentioned in this explanation.

80 In this figure, 18 is a master oscillator whose frequency is equal to the intermediate frequency of the receiver and 16 is a local oscillator the output of which is combined with the output of the master oscillator 18 at a mixer 17 and its sum frequency is supplied to a modulator 14. At the modulator 14, a continuous wave from the mixer 17 is modu-

lated to produce the above mentioned transmitting signal which is amplified at a radio frequency amplifier 13 and fed to an antenna 11 through a transmitting and receiving device

5 12.

The echo from a target is received by antenna 11 and fed through the transmitter-receiver 12 to a receiving mixer 15 where it is heterodyned by the output of the local oscillator 16 and converted to the intermediate frequency signal. An intermediate frequency amplifier 19 amplifies the received signal. A special decoding circuit 20 will be illustrated in Fig. 3. Although in Fig. 1 the special circuit 20 is placed at the intermediate frequency stage, it may be placed at the radio frequency stage.

In Fig. 3, 24 is a signal input terminal upon which a signal as shown in Fig. 1 is applied in the form of a radio frequency or intermediate frequency signal. The block 25 represents a delay circuit having a delay time  $\tau_2$  and 26 is an output terminal. The block 27 represents a delay circuit with a delay time  $\tau_1$  and 28 is an output terminal. Let it be assumed that both  $\tau_1$  and  $\tau_2$  have been selected to be an integral multiple of the carrier period. The block 29 is a phase-shifting circuit having, in the present example, a phase shift of 180 degrees. The block 30 denotes an output terminal, the output waveform being shown in Fig. 4(d).

Suppose, now, that a signal with amplitude  $a^1$  be applied to the terminal 24. Then pulse 1 arriving at the terminal 24 in the first place, arrives simultaneously at terminal 30 unchanged, becoming signal 31. At time  $\tau_2$  later, pulse 1 has passed through the delay circuit 25 and appears at its output terminal 26, but pulse 2 is not yet arrived at the terminal 24. So, pulse 1 appears at the output terminal 30 and becomes signal 32. After an elapse of a certain time interval, pulse 2 arrives at the terminal 24 and arrives simultaneously at the output terminal 30 as it is, forming signal 33. At this time, pulse 1 has not yet arrived at the terminal 28. When pulse 1 arrives at the terminal 28 finally, pulses 2 and 3 appear at the terminals 26 and 24, respectively. At the terminal 30 a pulse of amplitude  $3a^1$  is produced due to the superposition of pulses 1, 2, and 3 in the same phase since the phase of pulse 1 is shifted by 180° by the phase-shifting circuit 29. This is the pulse 34 in Fig. 4(d). Thereafter, pulses 35, 36, and 37 each with an amplitude  $a^1$  appear at the terminal 30. From the other point of view, when the pulses 1, 2 and 3 are applied to the input terminal 24 of the circuit of Fig. 3 separately, they produce the output as shown in Fig. 4(a), (b), and (c), respectively. So when pulses 1, 2 and 3 are applied in sequence as shown in Fig. 1, the output is a sequence of pulses as shown in Fig. 4(d) which is an addition of

the pulses shown in Fig. 4(a), (b), and (c). As a result, the pulse 34 only is three times higher than others because only at that moment the outputs for three input pulses add together in phase.

As will be evident from the above-mentioned description, in cases where the pulse train signal coded as shown in Fig. 1 is applied to the decoding circuit as shown in Fig. 3, the output signal is converted into one intense pulse signal and a number of small pulse signals. The ratio of the amplitudes, however, can be made the larger, the larger the number of elementary pulses. By an increase in the number of elementary pulses, the output signal can be made to be considered as one intense pulse. Such an additive large-amplitude signal is only available when the decoding circuit composed of the delay circuits and phase-shifting circuits is adapted for a particular pulse sequence of the transmitting signal coded to a particular phase. Such a large-amplitude receiving signal is not available in other cases.

For example, where pulses 1, 2, and 3 are all in phase in the above-mentioned example, a signal of amplitude  $3a^1$  as shown at 34 after these pulses have passed through the circuit of Fig. 3 is not available, only a signal of amplitude  $a^1$  being present. In order to interfere with such radar effectively, not only the intelligence related to the amplitude of the pulse series, but also the intelligence related to the phase coding must be measured, which is, as a matter of fact, next to impossible. Since the noise has no particular phase relationship such as this, no large noise will be produced. In other words, the present invention is also possessed of an effect of improving the signal-to-noise ratio.

#### WHAT WE CLAIM IS:—

1. A radar system including a transmitter to transmit a signal in the form of carrier wave pulses spaced in time in accordance with a particular code, means to vary the phase of the carrier wave in time in accordance with a particular code, and means to receive the transmitted carrier wave by a decoding circuit-arrangement having means to delay at least one portion of the received carrier wave with respect to another by a time interval dependent upon the spacing between the pulses and means to shift the phase of the said one portion of the carrier wave with respect to the other.

2. A radar system as claimed in claim 1 in which the decoding circuit arrangement has a plurality of received signal channels at least one of the said signal channels including a time delay network having a delay equal to the time interval between a pair of the transmitted pulses.

3. A radar system as claimed in claim 2, in which at least one of the said plurality

of signal channels includes means to shift with reference to the accompanying drawings.  
the phase of a portion of the received carrier  
wave by an amount equal to the phase varia-  
tion between a pair of the transmitted pulses.

5 4. A radar system substantially as described

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FIG. 1.

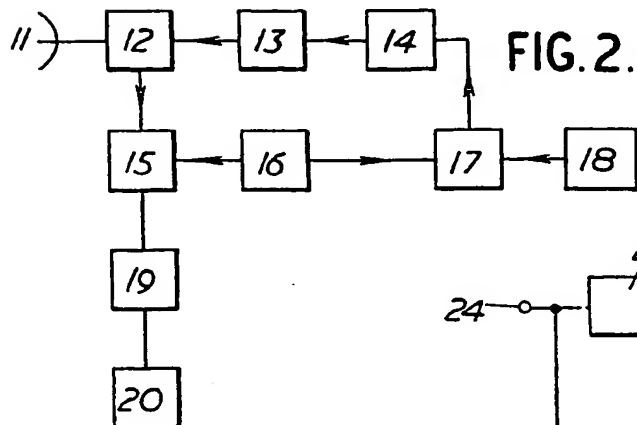
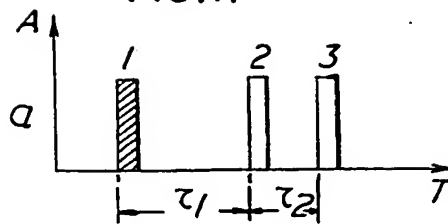


FIG. 2.

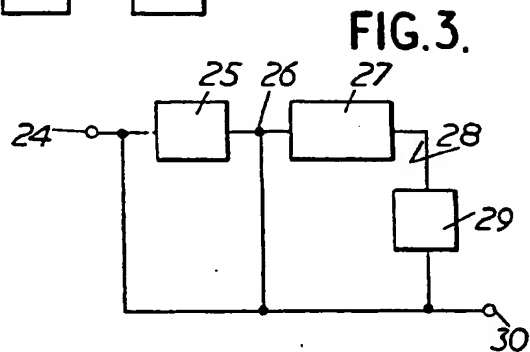


FIG. 3.

